Power Generation and Alternative Energy Branch
US Army RDECOM CERDEC CP&ID Power Division
Aberdeen Proving Ground, MD

PGAE - CR – 12 – 01

Military Energy Alternatives Conference

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
08 MAR 2012	**Presentation**	**08-03-2012 to 08-03-2012**

4. TITLE AND SUBTITLE **Military Energy Alternatives Conference**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Jonathan Cristiani**	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. ARMY COMMUNICATIONS-ELECTRONICS RESEARCH DEVELOPMENT AND ENGINEERING CENTER,5100 Magazine Rd.,Aberdeen Proving Ground,MD,21005-1852**	8. PERFORMING ORGANIZATION REPORT NUMBER **PGAE - CR - 12 - 01**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **U.S. ARMY COMMUNICATIONS-ELECTRONICS RESEARCH DEVELOPMENT AND ENGINEERING CENTER, 5100 Magazine Rd., Aberdeen Proving Ground, MD, 21005-1852**	10. SPONSOR/MONITOR'S ACRONYM(S) **RDER-CCA-PG** 11. SPONSOR/MONITOR'S REPORT NUMBER(S) **PGAE - CR - 12 - 01**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
An overview of the accomplishments of the CERDEC-managed American Recovery and Revinestment Act of 2009 for Smaller, Lighter Co-generation and Absorption Environmental Control Systems Program is provided.

15. SUBJECT TERMS
co-generation, absorption

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**22**	

Communications-Electronics Research Development and Engineering Center (CERDEC)

Military Energy Alternatives Conference

CERDEC
US ARMY– RDECOM

08 March 2012

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Jonathan M. Cristiani, Renewable Energy Team Leader
Army Power Division, Power Technology and Alternative Energy Branch

Overview

- CERDEC Introduction
- Technology Focus Areas, Applications, Objectives
- American Recovery and Reinvestment Act (ARRA) of 2009 for Smaller-Lighter Cogeneration and Absorption Environmental Control Technologies
- Innovative Cooling Equipment (ICE) Pending Solicitation

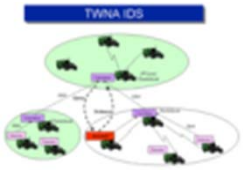
CERDEC Mission

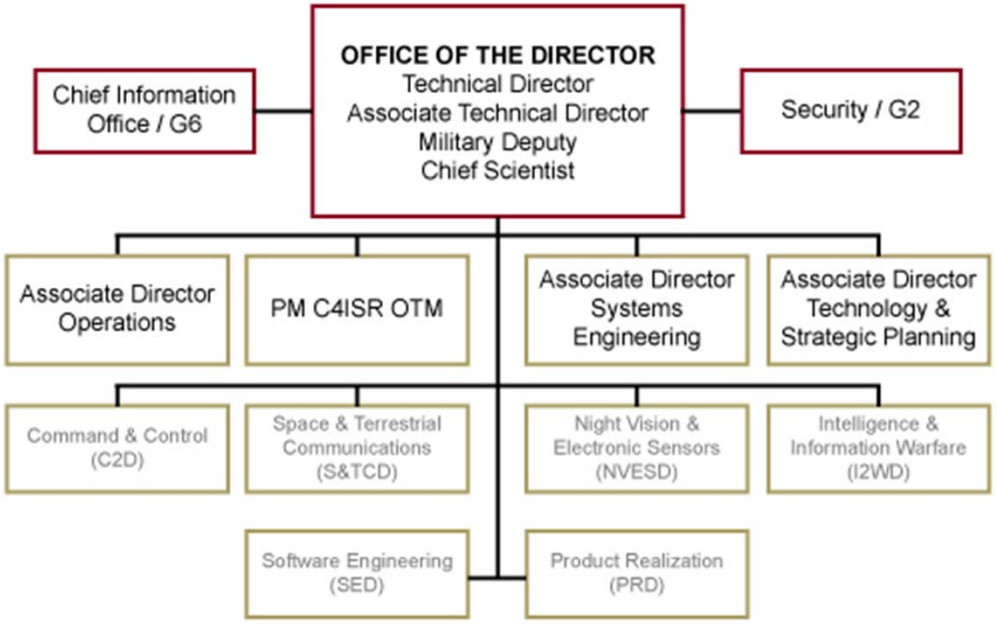
MISSION

To develop and integrate Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) technologies that enable information dominance and decisive lethality for the networked Warfighter.

VISION

To employ the imagination and innovation of this nation's brightest professionals to provide America's brave sons and daughters with the most effective solutions to ensure mission success and their safe return home.





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CERDEC Renewable Energy Team
Mission Summary

Enabling Technologies

- Hybrid Power
- Photovoltaic (PV), Solar Thermal, & Wind Energy Harvesting
- Waste-to-Energy (W2E) and Gas to Liquids (GTL)
- Waste heat recovery, Heat-actuated Cooling, & Co-generation

Applications

- Tactical Mobile Power
- Vehicle-mounted Auxiliary Power and Environmental Control
- Energy Security for Base Operations
- Waste abatement

Objectives

- Fuel Efficiency
- Force Protection
- Improved Mobility
- Reduced Signature
- Reduced Logistics

Alternative/Renewable Energy (A/RE) Tech Focus Areas, Applications, and Objectives

US Army CERDEC RE Team
A/RE Products, Metrics, Demos

Timetable	FY11	FY12	FY13	FY14
Portable Power (DLA / GSA / PM SWAR)		ARRA / AEWE		AEWE
Tactical Mobile Power (PM MEP / PM CP)	TSPS / AGSS	ASPS	ARRA/SBIR	NIE, OECIF / NIE
Vehicle Power (PM Tactical Vehicle / PM HTV)	TTI M915		SBIR	
Sustainment Power (PM FSS)	NZ+ JCTD	ARRA		OECIF / SIL

Encampment Waste to Energy & Biofuel
Beginning TRL 4; End Goal TRL 6
METRICS: 50 gallon biofuel per ton waste, 25 gallon per day fuel synthesis

Tactical Idle Reduction Equipment
Beginning TRL 6; End Goal TRL 7
APU METRICS: 5 kW, < 600 lbs, < 0.6 gph
ECU METRICS: 1 RT at 125 F in / 90 F out
TTA Status: Signed

Portable Solar Photovoltaic (PV) Modules and Mobile Hybrid PV Power Sources
Beginning TRL 3
FY11 Goal TRL 5; FY14 Goal TRL 6
METRICS: 75 W/kg, 150 W/m2, $2.50/W

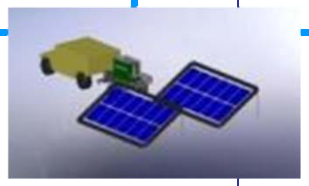
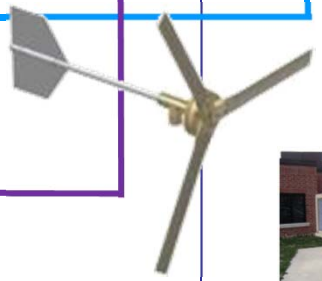
Wind Turbines and Deployment Structures
Beginning TRL 3; End Goal TRL 5
METRICS: 100 W at 20 mph, 45 lbs stowable system including MPPT and power electronics

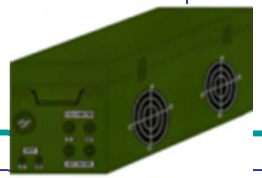
Heat Actuated Cooling and Cogeneration Systems
Beginning TRL 3/4; FY13 TRL 5, FY14 TRL 6
FY13 METRICS: COP 0.7, 45 kg/ton









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US Army CERDEC Applications
Portable Power

NOW

DAGR

LMR

P-Beacon

AN/PVS 14

Head Set

MBITR

Sure Fire Light

Mag Lite

PEQ-2A

Mark VII

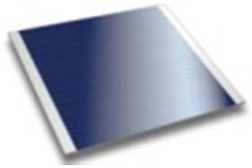
M68 CCO (Day)

HTWS (Night)

7 Battery Types
72-hrs:
70 Batteries, 16 lbs
(not including network radio)

Army Rifleman

FUTURE



AN/PVS 14

Head Set

MBITR

Sure Fire Light

Mag Lite

PEQ-2A

Mark VII

M68 CCO (Day)

HTWS (Night)

5 Battery Types
72-hr mission:
38 Batteries, 12.5 lbs
(not including network radio)

US Army CERDEC Applications
Tactical Mobile Power

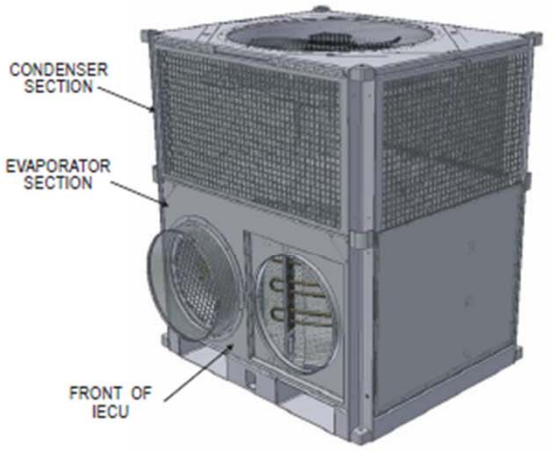
"During wartime, generators become the largest single fuel consumers on the battlefield… Gen-sets in Iraq [are] overwhelmingly used for space-cooling"

Category	Peacetime OPTEMPO	Wartime OPTEMPO
Combat Vehicles	30	162
Combat Aircraft	140	307
Tactical Vehicles	44	173
Generators	26	357
Non-Tactical	51	51
Total	**291**	**1040**

Army Fuel consumption in peacetime & wartime (million gallons per year)

Ref: USD(ATL) / Defense Science Board "More Fight Less Fuel" Feb 2006.

US Army CERDEC Applications
Tactical Environmental Control



Ref: Mr. Jeff Taylor, PM MEP, Presentation to JOCOTAS Technical Working Group dated November 2009

Military IECUs vs. Commercial A/Cs

Centralized ECU management will reduce the purchase and use of commercial equipment to replace standard military systems.

Improved Environmental Control Units

- ✓ Designed to operate to 125°F
- ✓ Cooling capacities rated at 125°F
- ✓ Organically supportable
- ✓ Improved NBC and EMP survivability, reduced aural and IR signatures
- ✓ Ruggedized for field use
- ✓ Soft start, limited inrush current
- ✓ High reliability in mission environments

Commercial A/C Equipment

- ✘ Designed to operate only to 100°F
- ✘ Cooling capacities rated at 90°F; performance degrades rapidly at temperature extremes
- ✘ Supportable only through contractor support
- ✘ No NBC or EMP survivability, or reduced aural or IR signatures
- ✘ Not ruggedized for field use
- ✘ High inrush current increases size of power generation equipment
- ✘ Reduced reliability in mission environments

ARRA for Cogeneration

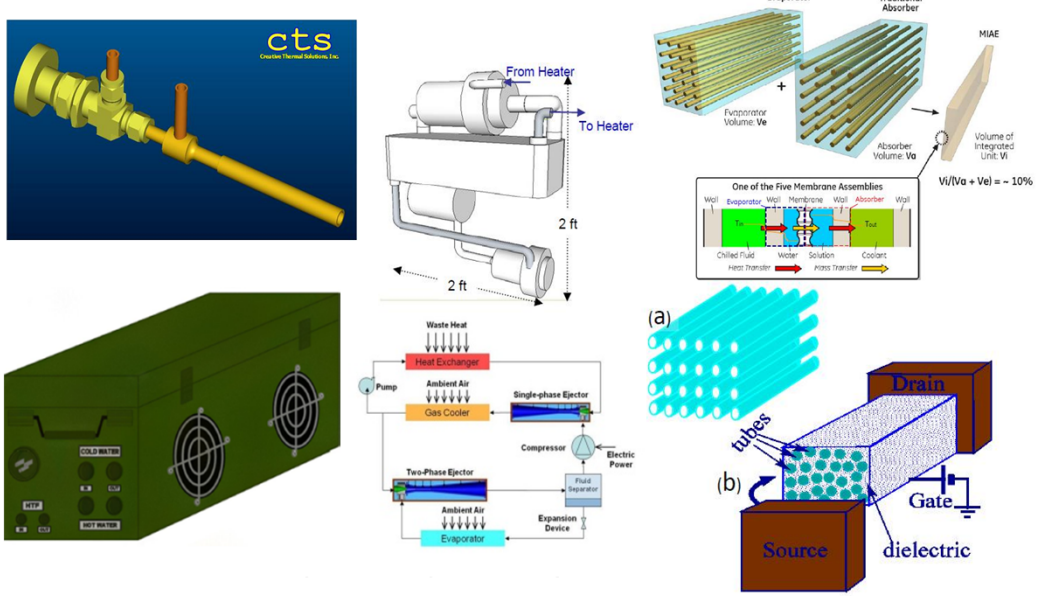
ARRA for Smaller, Lighter Co-generation and Absorption Environmental Control Systems

Project Objective:

The overall objective of this program is to demonstrate the co-generation of cooling, heating, and power from waste heat sources, which may include but are not limited to diesel engine exhaust gases, engine cooling fluids, and ambient airstreams.

Approach:

Emphasis of the advanced hardware demonstrations will be on equipment mobility, compact and lightweight design, refrigerant safety (non-flammable, lower toxicity), and compatibility with military standard diesel generator systems as a source of waste heat for initial demonstration.



Benefits/Metrics:

It is well known that environmental control represents one of the most significant load requirements on the tactical battlefield today. These conditions present a unique opportunity for demonstration and transition of a smaller, lighter combined heating, cooling, and power system that provides energy efficiency and logistical benefits over the baseline stand-alone equipment. Threshold metrics at end of program: TRL 5, 45 kg/ton dry weight, Coefficient of Performance (COP) [Cooling Out / Heat In] = 0.5

ARRA for Cogeneration
Primary Contracts

Contractor	Purpose / Status
Creative Thermal Solutions (CTS) with University of Illinois Urbana-Champaign (UIUC)	Development of a 10.5-kWt (3-ton) diesel-engine-waste-heat-driven ejector heat pump environmental control unit (ECU) that uses carbon dioxide refrigerant.
Stone Mountain Technologies Inc (SMTI) with Georgia Institute of Technology (GIT)	Development of a 2-kWt (0.6-ton) diesel-engine-waste-heat-driven ammonia-water absorption environmental control unit (ECU) that uses micro-scale heat exchanger technology.
GE Global Research (GEGR) with University of Maryland (UMD)	Development of a hydrophobic porous membrane-based integrated absorber and evaporator heat exchange device for a target 5.3-kWt (1.5-ton) lithium bromide absorption cycle.
United Technologies Research Center (UTRC)	Development of a 17.6-kWt (5-ton) hybrid vapor compression cycle with two-phase ejector heat pump using carbon dioxide refrigerant.
Energy Concepts with UMD	Development of a 10.5-kWt (3-ton) combustion waste heat driven ammonia water absorption chiller

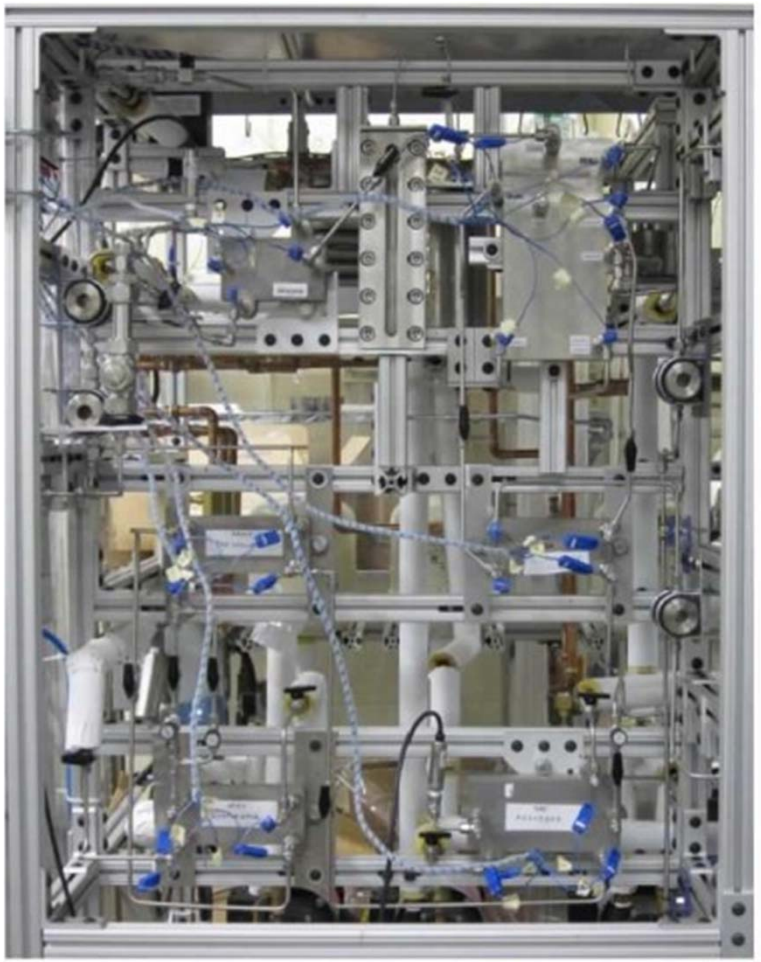
ARRA for Cogeneration
CTS / UIUC

- Carbon dioxide vapor compression cycle (VCC), separate work and heat recovery ejector heat pump cycles
- Trailer-mounted TRL 5/6 demonstrator to be delivered in Apr 2012

- Work recovery ejector cycle increase to VCC COP of up to 7% in range of relevant environments
- Waste heat ejector cooling capacities of up to 1.5 kW were achieved with waste-heat input of 6 kW (COP=0.25 and electrical power < 300 Watts)

ARRA for Cogeneration
SMTI / GTI

- Ammonia water absorption
- TRL 4 integrated breadboard to be delivered in Mar 2012
- Novel micro-scale heat and mass exchanger technology using low-cost brazing fabrication techniques
- COP = 0.65 based on thermal energy was demonstrated during multiple test runs during contract
- Potential for dual-use of the technology in heat pump water heater applications



ARRA for Cogeneration
GE Global / UMD

- Lithium bromide absorption
- TRL 3 component test stand transitioned to GE for continued internally-funded advancement
- Novel membrane integrated absorber evaporator (MIAE) component advancement and feasibility demonstration
- Comprehensive anti-crystallization strategy development including novel separate sensible and latent cooling (SSLC) approach

ARRA for Cogeneration
UTRC

- Carbon dioxide vapor compression with hybrid work/heat ejector heat pump cycle
- TRL 5 technology demonstrator delivered Oct 2011 to APG
- Advanced controller design to optimize complex set of operating parameters across three conditions: Army 125, DOE A, and DOE B

- Final (work recovery ejector only) demonstrator showed COP=1.93 at 125 F, a 16% improvement over baseline

ARRA for Cogeneration
Energy Concepts / UMD

- Ammonia-water absorption
- TRL 5/6, third-generation packaged technology demonstrator to be delivered in July 2012
- Novel micro-groove heat exchanger technology from UMD for solution heat exchanger and evaporator components, potential to substantially reduce weight
- Highest COP for absorption chiller demonstrated under ARRA to-date at 0.66 at 125 F

ARRA for Cogeneration
Final Projected Metrics

Contractor	Cycle	Refrigerant	TRL	Capacity	Proj. COP	Mass	Mass/Cap.	Delivery
			#	*RT*	*[Cooling Out / Electric In]*	*kg*	*kg/RT*	*MM-YY*
CTS	Ejector/VCC	CO2	5/6	3.1	1.3	233	75	04-12
UTRC	Ejector/VCC hybrid	CO2	5	5	1.9	400	80	09-11
			#	*RT*	*[Cooling Out / Heat In]*	*kg*	*Kg/RT*	*MM-YY*
GE	Absorption	LiBr-H2O	3	1.5	0.63	136	79	10-11
SMTI	Absorption	NH3-H2O	4	0.6	0.60	35	58	03-12
EC	Absorption	NH3-H2O	5/6	3.8	0.66	230	60	07-12
			#	*RT*	*[Cooling Out / Electric In]*	*kg*	*kg/RT*	*MM-YY*
IECU	VCC	R-410A	8	0.75	1.3	60	79	N/A
IECU	VCC	R-410A	8	1.5	1.8	105	70	N/A
IECU	VCC	R-410A	8	3	1.4	148	49	N/A
IECU	VCC	R-410A	9	5	1.6	255	51	N/A

All capacities rated at 125°F ambient (dry bulb), 90°F indoor (dry bulb), 75 indoor (wet bulb).
Values herein are projections and early test data from developmental project deliverables based on different technologies and assumptions, and require independent validation.

ARRA for Cogeneration
Test Plan

- All deliverable equipment will be tested in dual-room psychometric chamber according to ASHRAE 37 (Methods for testing electrically-driven unitary air conditioning and heat pump equipment)
- Army 125/90/75, DOE A, and DOE B rating conditions
- Exception is trailer-mounted power and cooling system from CTS, which will be tested in chamber with appropriate exhaust system
- Independent validation of final projected metrics on last slide is expected to be achieved by mid-FY13
- Transition test results and most promising technologies to the….

Operational Energy Capabilities Improvement Fund (OECIF) Innovative Cooling Equipment (ICE)

MOTIVATION:

- Heating, ventilation and air conditioning (HVAC) for tactical electronics functionality and Warfighter sustainment in contingency operations represents one of the most significant operational energy challenges for DOD
- Through the implementation of state-of-the-art advancements (TRL 5+) in HVAC technology, an operational efficiency improvement of 10% for the DOD fleet of environmental control units (ECUs) would result in a fuel savings of nearly 3.3M gallons per year

PROGRAM PLAN / DESCRIPTION:

MILESTONES	FY12	FY13	FY14
Market survey, baseline			
Component fab, breadboard	5		
Integrated system build/test		6	
Operational Experimentation			7
Transition to Acq Programs			

MILITARY BENEFIT:

- Detailed market surveys - Advanced and hybrid HVAC annual cycle models - Updated ECU operational performance baseline
- Near-term product improvement / technology insertions to multi-service programs of record
- 30% operational energy savings demonstrated via operational demonstrations/experimental tests during 2013 – 2014
- Sustainable infrastructure for continued advancement and adaptation of HVAC technologies for tactical environmental control applications

Closing

- CERDEC is US Army's center of excellence for C4ISR research and development
- Mission focus is TRL 3-7 for both Soldier and Mobile Power & Energy applications
- ARRA for Cogeneration is complete and hardware deliverables are being received/tested during FY12
- ICE is follow-on to ARRA for Cogeneration and solicitation will be on the street soon!